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FABRICATION AND EXCITATION OF
THE DISK AND WASHER LINAC STRUCTURE

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When considering a new linac structure, such as the Disk and Washer (DAW) Linac Structure[1] for a new application such as a Race Track Microtron, it is useful to make specific comparisons between the new structure and those structures in common use for electron acceleration. The most common electron linac structure in our major accelerator facilities today is the disk-loaded, traveling-wave linac structure of the type developed at SLAC, NBS, MIT, Frascati and Saclay. An attempt is made below to compare a scaled version of a typical disk loaded structure with a proposed version of the Disk and Washer Structure for the CW Race Track Microtron application.

Table I. Comparison of Linac Structure Parameters.

	SLAC ($2\pi/3$)	Disk Loaded (traveling wave) (scaled)	DAW (standing wave)
freq	2856	1320	1320
τ	.57	.57	
Length (m)	3.05	10.0	10.0
Z_o (MΩ/m)	56.5	38.4	116.0*
Z_{eff} (MΩ/m)	38.4	26.1	76.8*
ΔW (MeV)		17	17
P_o (MW)		1.11	0.37
U (J)		2.60	2.30
Q_o	13200	19417	51682
t_f (μsec)	.83	4.00	14.00**
V_g/C	.0122	.0083	.50

*degraded 10% from SUPERFISH.
**for 25% overdrive with unity coupling.

The structure proposed for this application by NBS/LASL is a 10-meter-long disk and washer section operating at 1320 MHz with a total single-pass acceleration of 17 MeV. Some of the pertinent parameters for this section are presented in the right-most column of Table I, such as the effective shunt impedance (ZT^2), the cavity power, the stored energy, the unloaded Q, the cavity fill time, and the group velocity.

For the sake of comparison, some of the pertinent parameters for the 10-foot, 2856 MHz SLAC section, and a scaled version of a typical structure, are presented in the first two columns of Table I.

Leiss pointed out in 1972[2] that the relative merits of traveling wave and standing wave structures can be compared by use of an effective shunt impedance defined as

$$Z_{eff} = \frac{(\text{Energy Gain/Section Length})^2}{\text{Power Loss/Section Length}} .$$

He noted that the value of this quantity (scaled to 2856 MHz) for all modern traveling wave linacs is in the range of 40 MΩ/m ± 10%. He also noted that the corresponding quantity for the electron prototype of LAMPF (standing wave) was 86.9 MΩ/m, or more than two times the traveling wave value. With the latest developments reported by Schriber, the effective shunt impedance of the disk and washer structure is 76.8 MΩ/m at 1320 MHz, which scales to 113.0 MΩ/m at 2856 MHz, or nearly three times the traveling wave value.

Table I indicates that a power of 1.11 MW is required to excite the traveling wave structure to an acceleration of 17 MeV in a length of 10 meters, while only one third of that is required for the same acceleration rate in the standing wave structure. At these excitations, the traveling wave structure has slightly more stored energy than its standing wave counterpart. The Q's listed in Table I are consistent with the stored energy and power parameters.

The fill time for the traveling wave structure is just the structure length divided by the average group velocity. The fill time given for the standing wave structure corresponds to a 25% overdrive with unity coupling. The energy expended in filling the structures is 4.4J in the traveling wave case, and 6.4J in the standing wave case.

It is worth noting that the group velocity of the standing wave structure is 60 times higher than that of the traveling wave structure.

Figure 1 shows one and a half cells of the disk-loaded structure and one cell of the disk and washer structure on the same scale. The field lines show the direction of the electric fields at a particular moment in the cycle. The line spacing cannot be interpreted as an indication of field intensity.

The outer diameter of the disk and washer structure is roughly twice that of the disk loaded structure, and the washer of the former is roughly the size of the disk in the latter. At equivalent excitations (Table 1), the power density on the washer is approximately one-third of that on disk of the disk loaded structure.

Fabrication

Until recently we had considered the disk and washer structure to be made up of a series of unit cells, each consisting of a section of outer wall of length $\beta\lambda/2$, one disk, and one washer supported from the disk by four L-shaped supports as shown in Figure 2.

One serious objection to this geometry is the strong left/right asymmetry introduced by the L-shaped washer supports. This asymmetry, if not carefully tuned out, will cause the fields to tilt toward one end of the tank.

For much of the last year, we debated more symmetrical washer support geometries, such as T-shaped supports, and a variety of fabrication techniques. Our current design is based on the use of I-shaped washer supports as shown in Figure 3. These supports have the desired symmetry and lend themselves to a multicell fabrication. Detailed cost estimates suggest that this multicell configuration can be built at 1320 MHz for about $11K/m, or about two-thirds the cost of the unit-cell type of fabrication.

We are currently in the process of building the meter-long section shown in Figure 4, as a representative section of the coupled cavity portion of PIGMI. The washer spacing and washer cooling suggested in this drawing are not appropriate for a cw electron linac.

The support and cooling of the washer is recognized as the major engineering problem of the disk and washer structure. It is the cooling of the washer that will limit the excitation of this structure for cw applications.

For the race track microtron application, we propose a cavity power dissipation of 370 kW in 10 meters, or 37 kW/m. At 1320 MHz, the cell length is 11.356 cm and the power dissipation is 3.26 kW/cell. Eighty percent of the cell power, or 2.6 kW, is dissipated on the washer.

The cooling circuit for the proposed washer is shown in Figure 5. Water flow and heat removal calculations were based on a washer power load of 2.6 kW. At a pressure drop across each quadrant of 0.43 psi, the water flow through each quadrant is 3.8 gpm at an average velocity of 14 fps. The temperature of the water will increase about 1° F from the inlet to the outlet. The copper will run about 20° F hotter than the water and will have only a few degrees of variation over the washer volume.

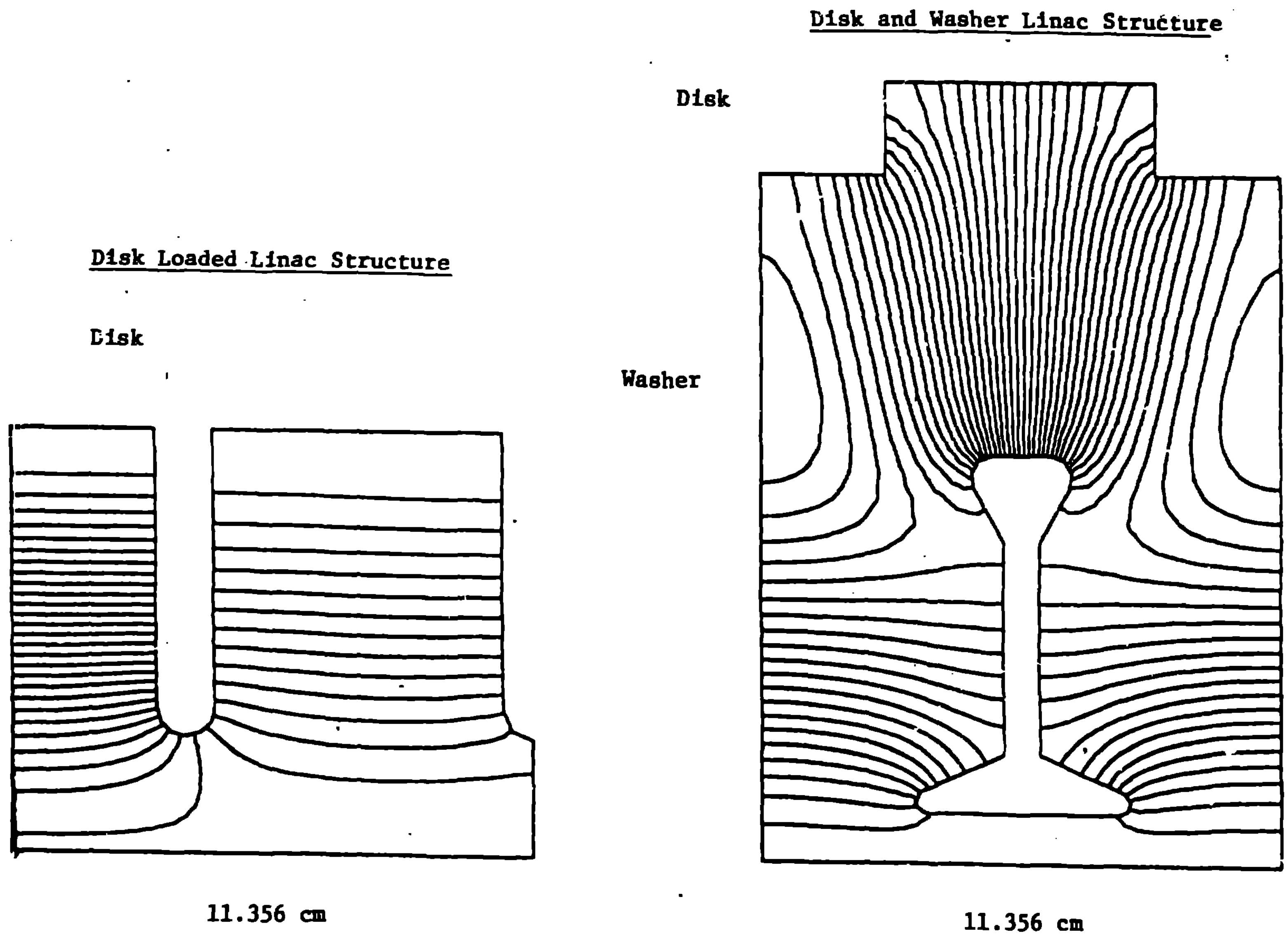

Fig. 1. Comparison of Linac Structure Geometries (1320 MHz).

DISK AND WASHER LINAC STRUCTURE

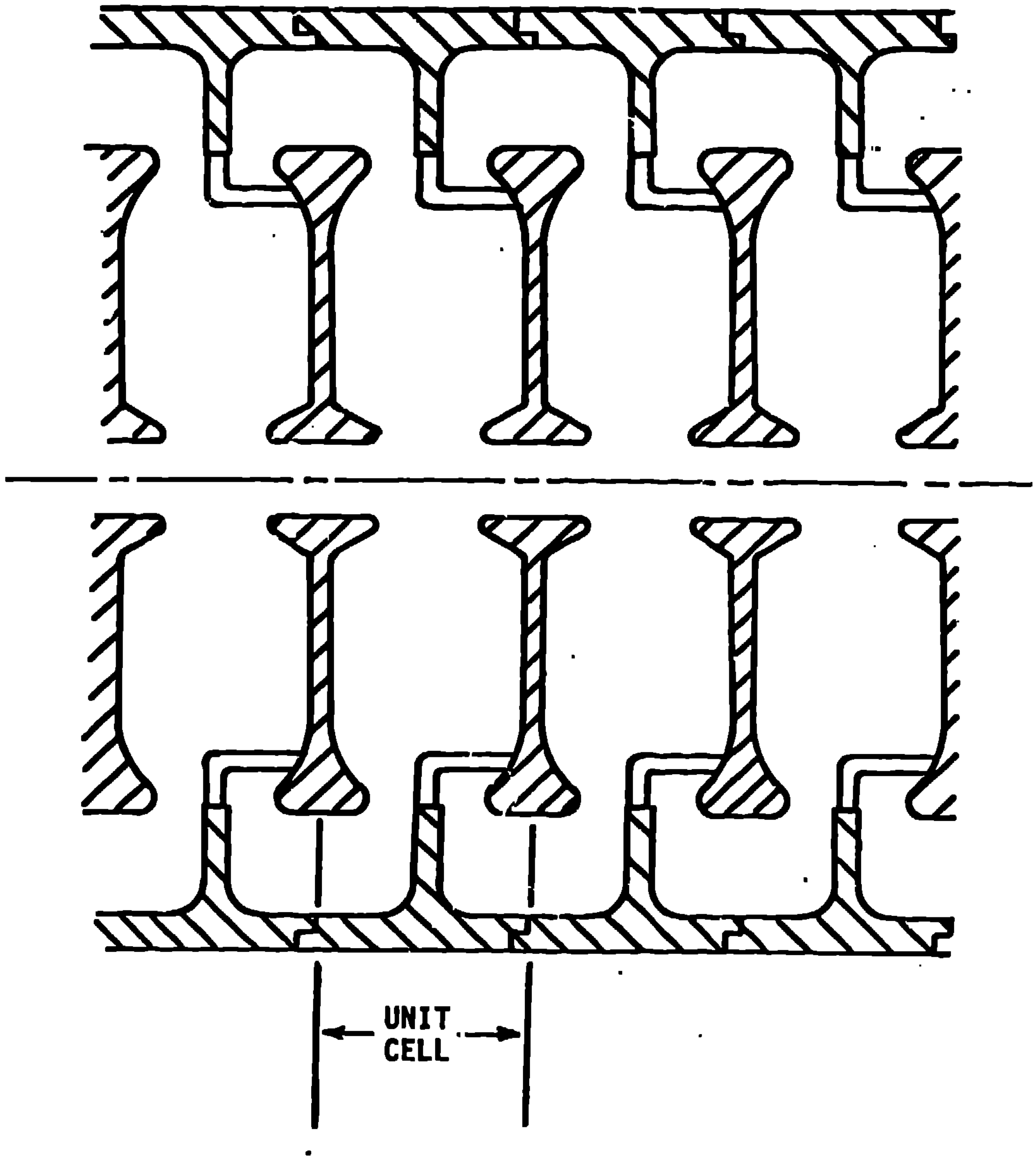

Fig.2 The Unit Cell Configuration of the Disk and Washer Linac Structure.

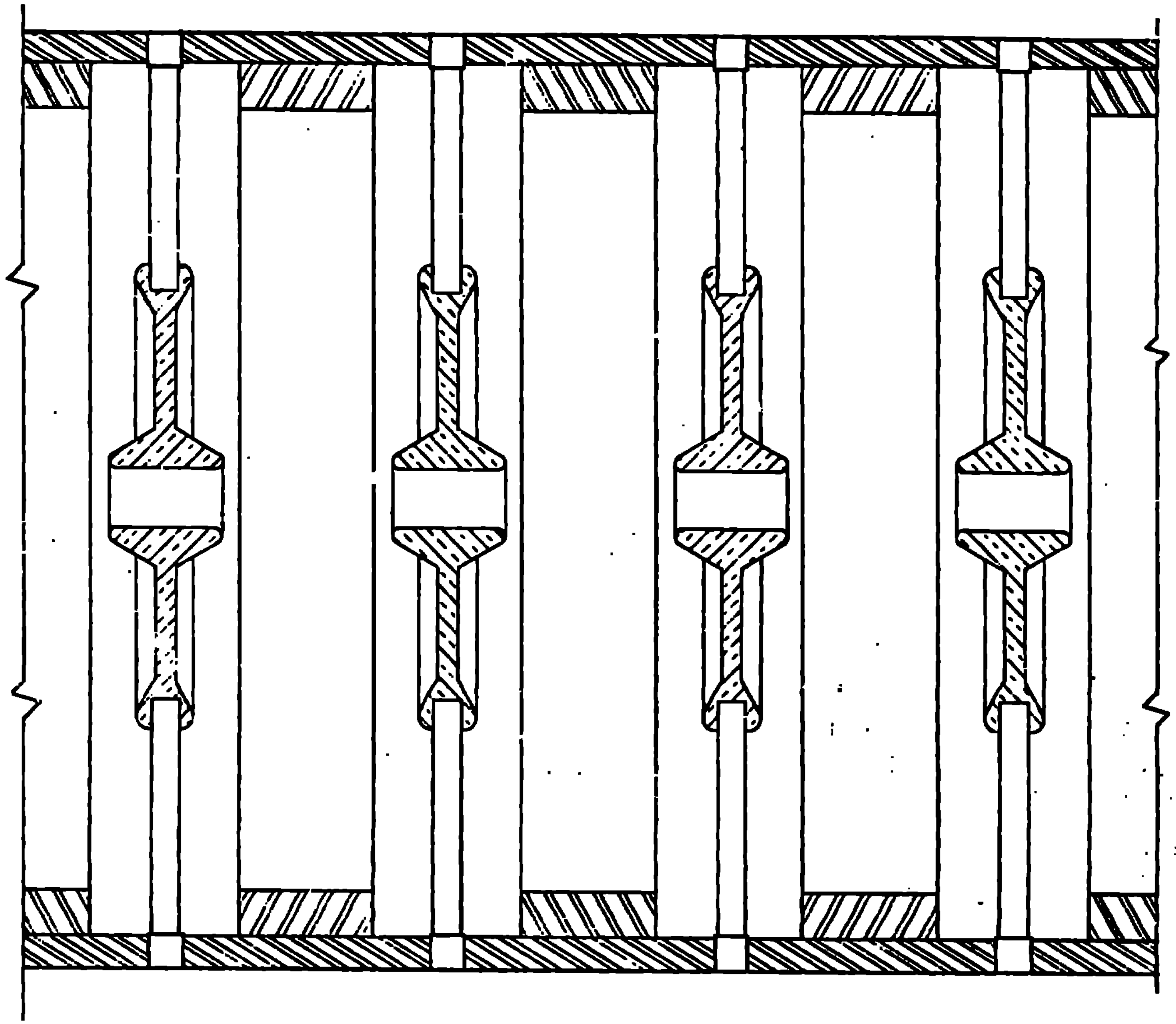

Fig. 3. The Multicell Configuration of the Disk and Washer Linac Structure.

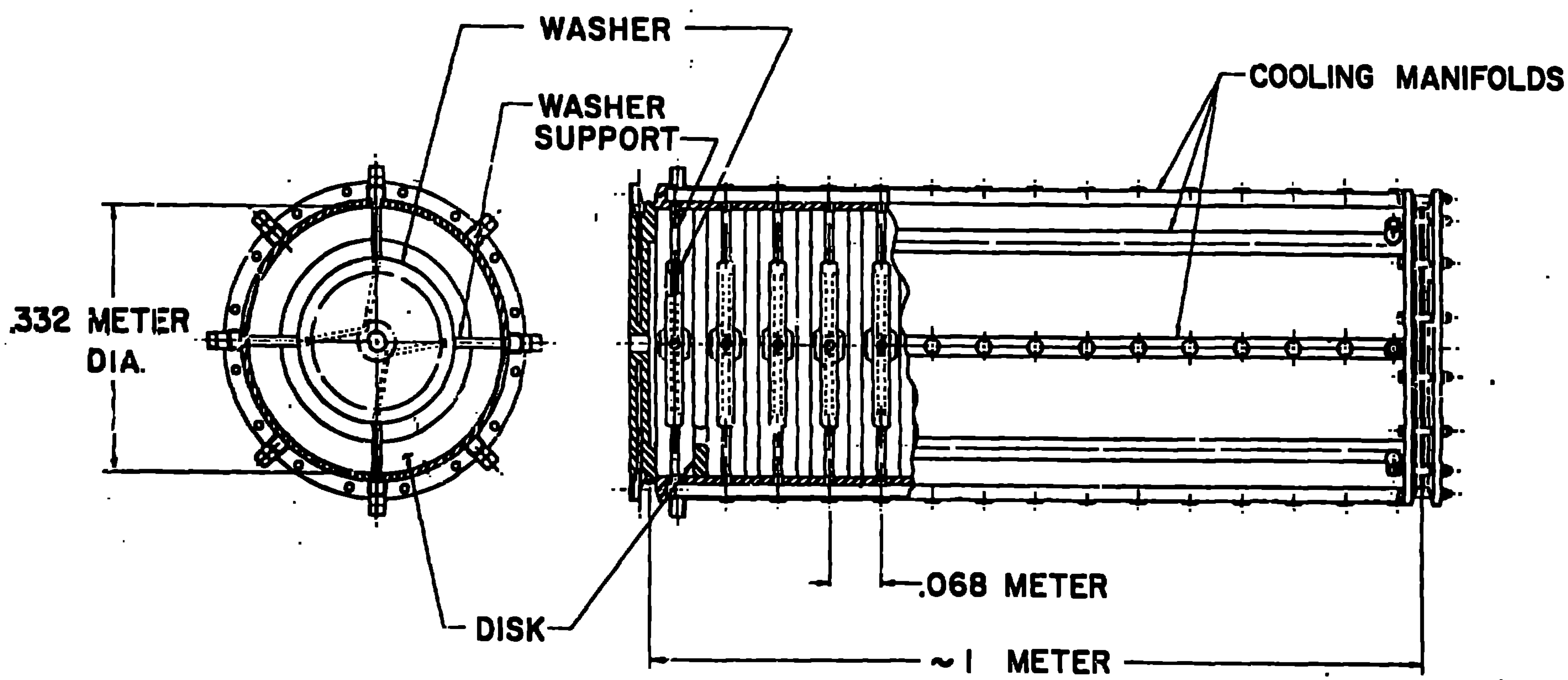

Fig. 4. **DISK AND WASHER LINAC STRUCTURE**

15 CELL SEGMENT 1320 MHz $\beta = 0.6$

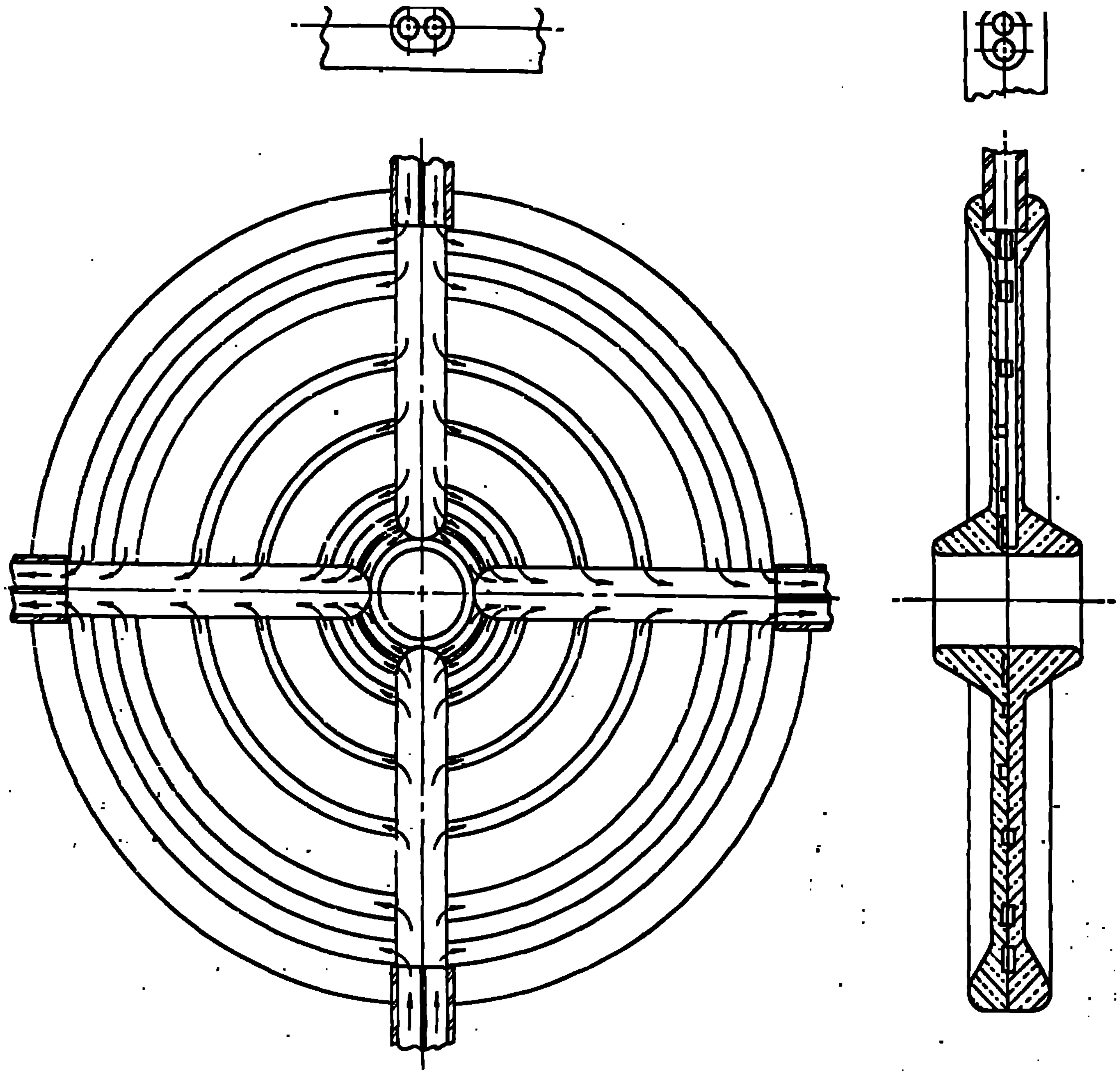

Fig. 5 Proposed washer cooling circuit.

In the proposed multicell format, the cooling manifolds on the tank sections cool the tank walls and disks, in addition to serving as tidy manifolds for the supply and return of water to the washer supports.

For reasons of fabrication, tuning transportation, installation, and maintenance, the meter-long section may prove to be a convenient unit. The sections are designed to join together as shown in Fig. 6. A special disk is made with a larger outer diameter. This disk is clamped between the tank segments, which are initially bolted together and then welded. The joint is designed so that the weld can be ground off and the tanks separated if necessary.

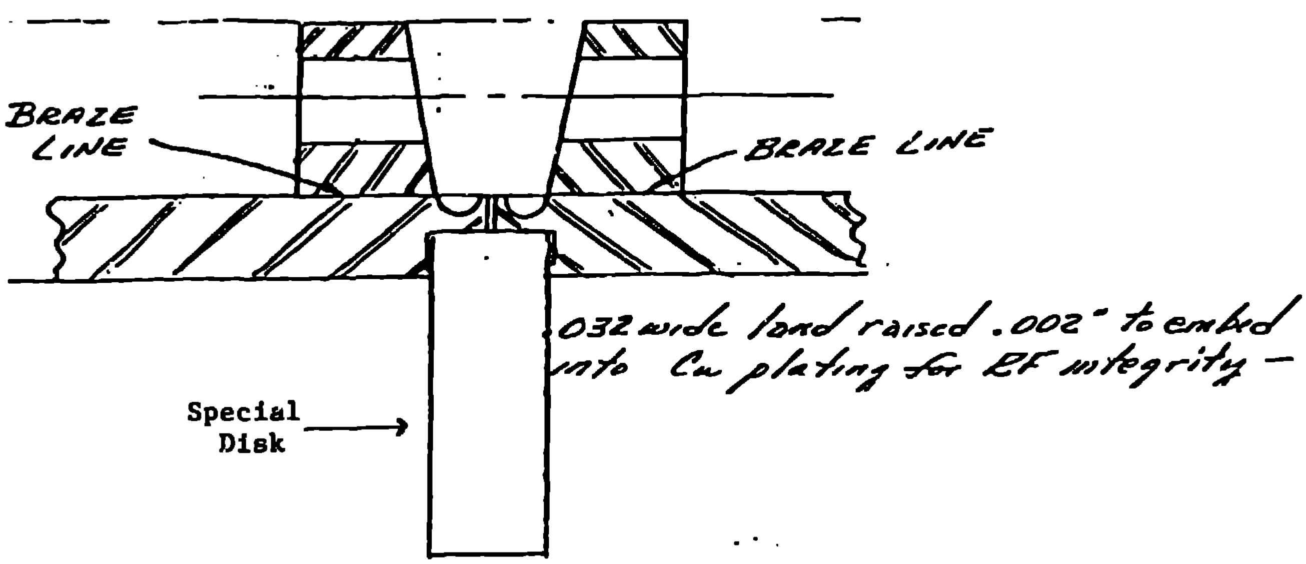

Fig. 6. Tank Section Joint--bolted and welded.

Excitation

The fields of the accelerating mode and the coupling mode transform nicely into the TEM mode of a cylindrical coax as shown in Fig. 7. This suggests the possibility of terminating the structure in a short section cylindrical coax, or forming a coaxial bridge coupler,[3] as shown in Fig. 8, to bridge around a beam focusing element or beam diagnostic device. The coaxial section has a region of strong magnetic field near the outer wall, which represents a good place to drive the structure with a loop or window.

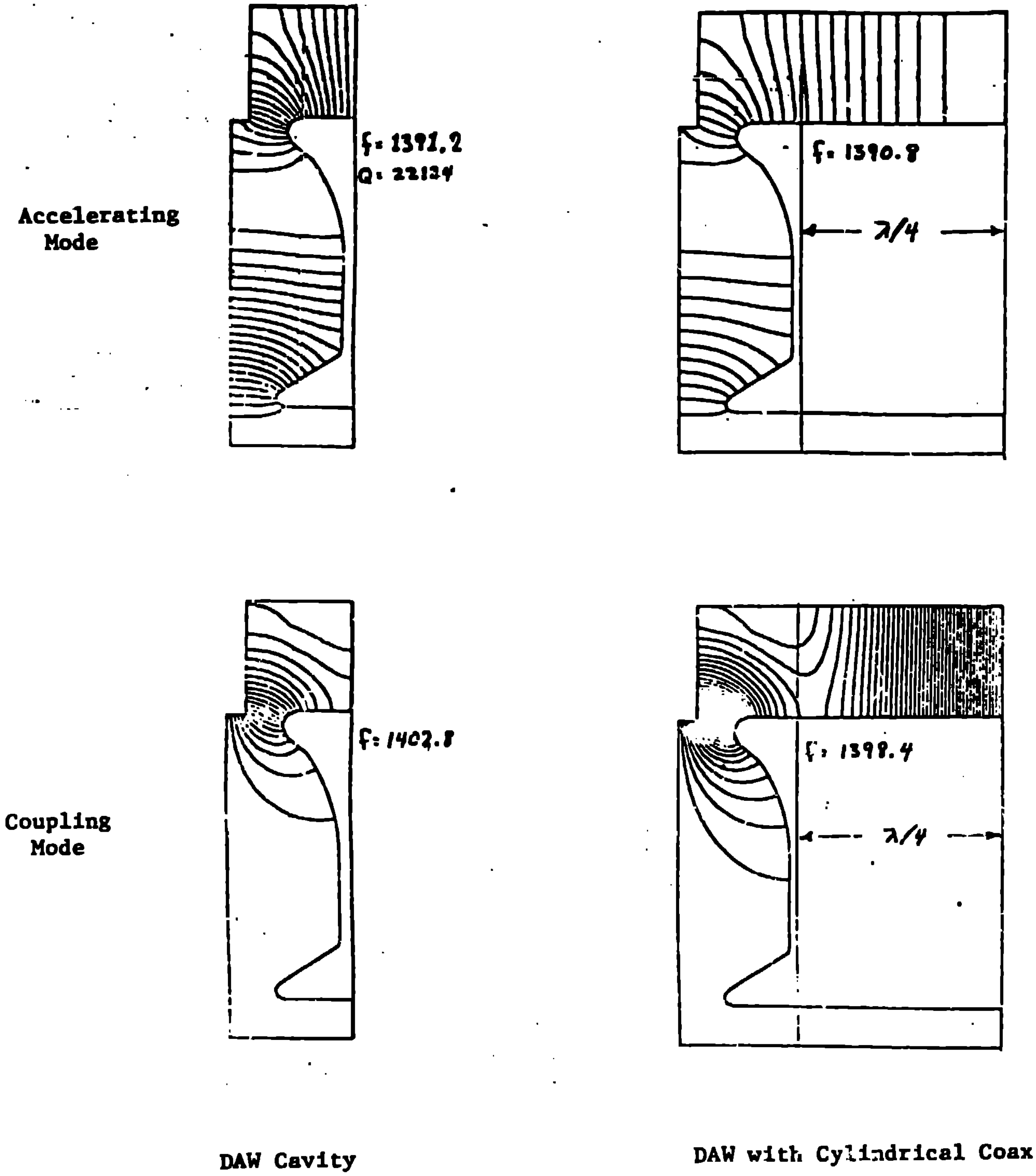

Fig. 7 Transformation of DAW Modes to TEM Mode of a Cylindrical Coax

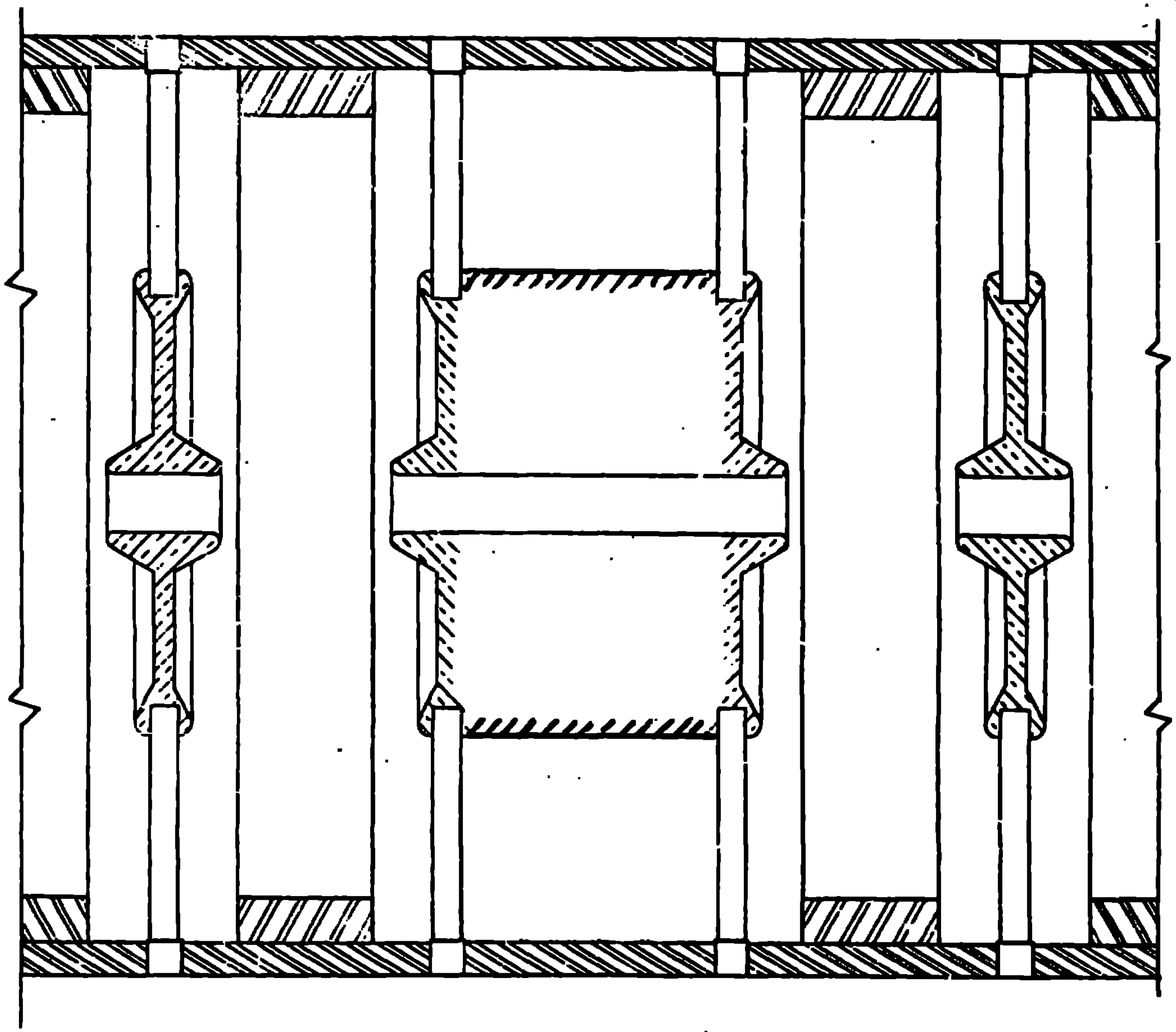

Fig. 8. A possible coaxial bridge coupler geometry.

The proposed microtron is to be a 10-turn racetrack microtron with an output energy of 175 MeV and an average current of one mA. The energy is realized by an injection energy of 5 MeV followed by 10 recirculations at 17 MeV each. The beam loading on the main linac section is 170 kW and the cavity power is 370 kW.

An rf power source of approximately 500 kW will be needed for the accelerating section at the contemplated operating frequency of 1320 MHz. The highest cw power klystron known to be commercially available at 1320 MHz is rated at 60 kW. While it is possible to satisfy the power requirements with multiple drivers, such an arrangement would be most costly and less reliable than the simpler one-tube configuration. There are, however, no known technical obstacles to achieving a 500 kilowatt L-band source. Five hundred kilowatt cw klystrons are commercially available at 353, 500 and 2400 MHz. A new klystron for 1320 MHz would, however, require development. Depending on cost and time, it is proposed that the tube be developed commercially or in-house at LASL.

Several klystron analysis codes exist at LASL and these codes have been used to design a klystron for LAMPF, which was built by an outside vendor and which demonstrated a 60% conversion efficiency. The capability to build such a klystron at LASL also exists in the LAMPF klystron rebuilding facility should the economics favor such a source. The tube would have a gain of the order of 50 dB and the necessary phase and amplitude modulation would be accomplished in the low level (<10 w) drive stage.

The dc power supply for the 500 kW klystron can be of conventional design. Assigning a tentative gun microperveance of 0.75 and a dc-to-rf conversion efficiency of 0.70 to the proposed klystron, a 65 kV, 12A power supply is required. The supply would employ SCR's in the rectifying circuit to provide quick disconnect capability and limited range voltage control. Coarse voltage control would be accomplished by induction voltage regulators. Rectifier pulse multiplicity versus active or passive filtering will be examined in a system context. The power supply is well within present commercial technology.

Acknowledgments

This report is a brief account of the work of a number of people in the Linac Technology Group of the Accelerator Technology Division at LASL. The structure analysis is primarily the work of S. O. Schriber,[1] who is visiting this laboratory from the Chalk River Nuclear Laboratory, Chalk River, Ontario. Additional contributions to the structure were made by J. J. Manca, E. A. Knapp, J. M. Potter, P. Grand of the Brookhaven National Laboratory, and the author. The mechanical features of the fabrication are primarily the work of L. C. Wilkerson and P. Grand, and the rf power considerations are the work of T. J. Boyd, Jr., and P. J. Tallerico.

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1. S. O. Schriber, "Room-Temperature Cavities for High-Beta Accelerating Structures," this conference.

2. J. E. Leiss, "Modern Electron Linacs and New User Needs," Proc. of 1972 Linear Accelerator Conference, pp. 197-204.

3. J. J. Manca, "RF Coaxial Couplers for High Intensity Linear Accelerators," LASL Report to be published.